DOE Boiler MACT
Technical Assistance Program

Virginia DEQ

June, 2013

U.S. Department of Energy
Mid-Atlantic Clean Energy Application Center
Promoting CHP, District Energy, and Waste Energy Recovery

www.maceac.psu.edu

US DOE Regional Clean Energy Application Centers (CEACs)

- U.S. DOE Mid-Atlantic Clean Application Center originally established in 2001 by U.S. DOE and ORNL to support DOE CHP Challenge
- Today the 8 Centers promote the use of CHP, District Energy, and Waste Heat Recovery Technologies
- Strategy: provide a technology outreach program to end users, policy, utility, and industry stakeholders focused on:
  - Market analysis & evaluation
  - Education & outreach
  - Technical assistance

- Mid-Atlantis Website: www.maceac.psu.edu

U.S. Department of Energy
Mid-Atlantic Clean Energy Application Center
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Presentation Message / Take Away

- December 20th, 2012 U.S. EPA finalized Clean Air Act pollution standards which include:
  - Emission Standards for Major Source Industrial, Commercial, and Institutional Boilers and Process Heater (ICI Boiler MACT)
- Affected facilities are developing compliance strategies:
  - Significant costs involved
- Those large affected boilers utilizing coal or oil may consider:
  - Adding control technologies to existing boilers … Cost of compliance
  - Switch to natural gas boilers …Cost of compliance
  - Consider natural gas fueled gas turbine CHP …Investment vs. cost of compliance

Presentation Message / Take Away

- DOE, through its 8 regional Clean Energy Application Centers – (CEACs), is supplementing this effort by providing site-specific technical and cost information on clean energy compliance strategies to those major source facilities affected by the Boiler MACT rule currently burning coal or oil. The CEACs provide:
  - technical information and assistance
  - market development, and
  - education on Conventional CHP, Waste Heat to Power, and District Energy CHP options
- These affected facilities may have opportunities to develop compliance strategies, such as CHP, that are cleaner, more energy efficient, and that can have a positive economic return for the plant over time.

Presentation Message / Take Away

- Combined Heat & Power (CHP) is an important energy resource that provides
  - Benefits for U.S. Industries
    - Reducing energy costs for the user
    - Reducing risk of electric grid disruptions
    - Providing stability in the face of uncertain electricity prices

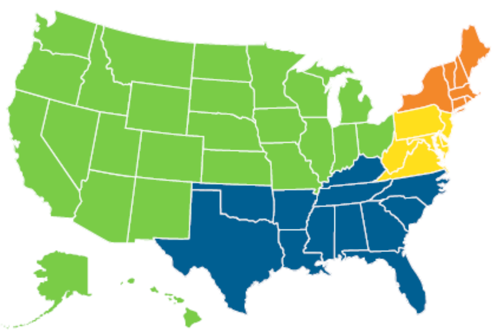
Presentation Message / Take Away

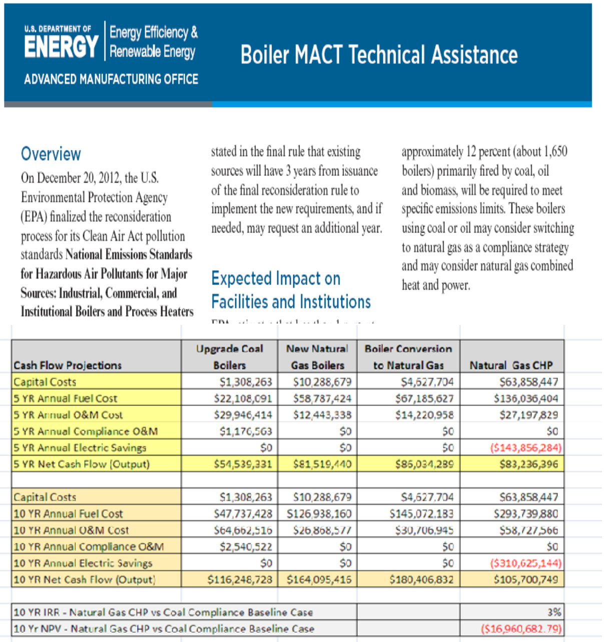
- Combined Heat & Power (CHP) is an important energy resource that provides
  - Benefits for the Nation
    - Provides immediate path to increased energy efficiency and reduced GHG emissions
    - Offers a low-cost approach to new electricity generation capacity and lessens need for new T&D infrastructure
    - Enhances grid security
    - Enhances U.S. manufacturing competitiveness
    - Uses abundant, domestic energy sources
    - Uses highly skilled local labor and American technology

Presentation Message / Take Away

- Take advantage of the DOE Boiler MACT Technical Assistance Program (Decision Tree Analysis):
  http://www.1.eere.energy.gov/manufacturing/distributedenergy/boilermact.html

Decision Tree Analysis





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ADVANCED MANUFACTURING OFFICE

Boiler MACT Technical Assistance

Overview

On December 20, 2012, the U.S. Environmental Protection Agency (EPA) finalized the reconsideration process for its Clean Air Act pollution standards **National Emissions Standards for Hazardous Air Pollutants for Major Sources: Industrial, Commercial, and Institutional Boilers and Process Heaters** stated in the final rule that existing sources will have 3 years from issuance of the final reconsideration rule to implement the new requirements, and if needed, may request an additional year.

Expected Impact on Facilities and Institutions

approximately 12 percent (about 1,650 boilers) primarily fired by coal, oil and biomass, will be required to meet specific emissions limits. These boilers using coal or oil may consider switching to natural gas as a compliance strategy and may consider natural gas combined heat and power.

Cash Flow Projections	Upgrade Coal Boilers	New Natural Gas Boilers	Boiler Conversion to Natural Gas	Natural Gas CHP
Capital Costs	$1,308,263	$10,288,679	$4,627,704	$63,858,447
5 YR Annual Fuel Cost	$22,108,091	$58,787,424	$67,185,627	$136,036,404
5 YR Annual O&M Cost	$29,946,414	$12,443,338	$14,220,958	$27,197,829
5 YR Annual Compliance O&M	$1,176,563	$0	$0	$0
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5 YR Net Cash Flow (Output)	$54,539,331	$81,519,440	$86,034,289	$83,236,396
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10 YR Annual Electric Savings	$0	$0	$0	($310,625,144)
10 YR Net Cash Flow (Output)	$116,248,728	$164,095,416	$180,406,832	$105,700,749
10 YR IRR - Natural Gas CHP vs Coal Compliance Baseline Case				3%
10 Yr NPV - Natural Gas CHP vs Coal Compliance Baseline Case				($16,960,682.79)

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EPA ICI Boiler MACT

- DOE efforts are focused on Major Source Boiler MACT
  - Standards for hazardous air pollutants from major sources: industrial, commercial and institutional boilers and process heaters (excludes any unit combusting solid waste)
- Major source is a facility that emits:
  - 10 tpy or more of any single Hazardous Air Pollutant, or 25 tpy or more of total Hazardous Air Pollutants (HAPs)
- Emissions limits applicable to new and existing units > 10 MMBtu/hr
  - Mercury (Hg)
  - Filterable Particulate Matter (PM) or Total Selective Metals (TSM) as a surrogate for non-mercury HAP metals
  - Hydrogen Chloride (HCl) as a surrogate for acid gas HAP
  - Carbon Monoxide (CO) as a surrogate for non-dioxin/furan organics

EPA ICI Boiler MACT (cont'd)

- Rule significantly impacts oil, coal, biomass, and process gas boilers
  - Emission limits must be met at all times except for start-up and shutdown periods
  - Controls are potentially required for Hg, PM, HCl, and CO
  - Also includes monitoring and reporting requirements
  - Limits are difficult (technically and economically) for oil and coal boilers (especially older units)

EPA ICI Boiler MACT (cont'd)

- Existing major source facilities are required to conduct a one-time energy assessment to identify cost-effective energy conservation measures
- Compliance must be met within 3 years from the publication of the final rule ---existing boilers may request an additional year if technology cannot be installed in time.
- For new and existing units < 10 MMBtu/hr – the rule establishes a work practice standard instead of numeric emission limits (periodic tune-ups)

Compliance Strategy

- Standard Control Technologies for Existing Boilers
  - Mercury (Hg): Fabric filters and activated carbon injection are the primary control devices
  - Particulate Matter (PM): Electrostatic precipitators may be required for units to meet emission levels
  - Hydrogen Chloride (HCl): Wet scrubbers or fabric filters with dry injection are the primary control technologies
  - Carbon Monoxide (CO): Tune-ups, replacement burners, combustion controls and oxidation catalysts are the preferred control technologies
  - Required compliance measures for any unit depend on current emissions levels from the units and the control equipment already in place

Compliance Strategy

- Convert boilers to burn natural gas (refinery & blast furnace gases are treated as natural gas in the rule)
  - Replace burners in existing boilers with natural gas burners (lose efficiency)
  - Replace boiler with natural gas boiler
  - Compliance becomes straight forward (tune-ups in lieu of more rigorous control options)

Compliance Strategy

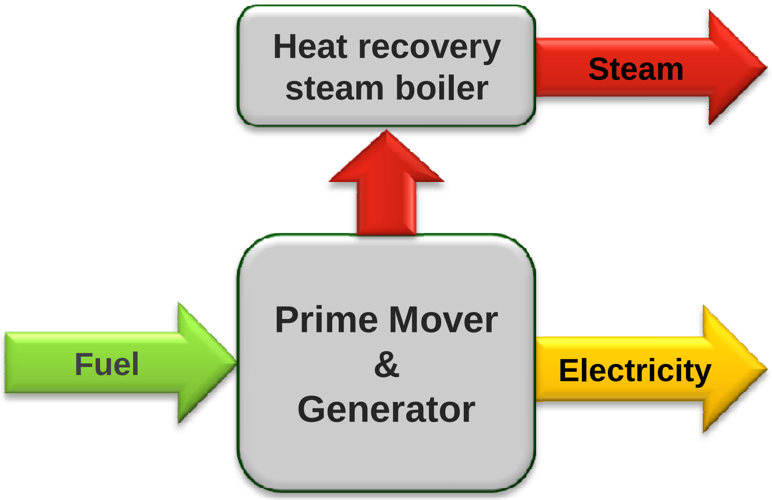
- Install a natural gas fueled Conventional CHP system
  - Gas turbine/generator produces electricity
  - Turbine waste heat generates steam through a HRSG
- Represents a tradeoff of benefits versus additional costs
  - Represents a productive investment
  - Potential for lower steam costs due to generating own power
  - Higher overall efficiency and reduced emissions
  - Higher capital costs, but partially offset by required compliance costs or new gas boiler costs

Defining Combined Heat & Power (CHP)

The on-site simultaneous generation of two forms of energy (heat and electricity) from a single fuel/energy source

Conventional CHP

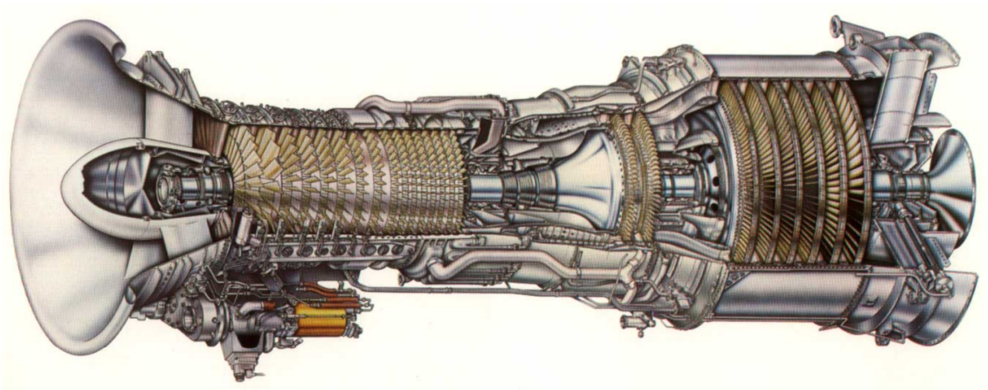
(also referred to as Topping Cycle CHP or Direct Fired CHP)



Recip. Engine
Gas Turbine
Micro-turbine
Fuel Cell
Boiler/Steam Turbine

- **Simultaneous generation of heat and electricity**
- **Fuel is combusted/burned for the purpose of generating heat and electricity**
- **Normally sized for thermal load to max. efficiency – 70% to 80%**
- **HRSG can be supplementary fired for larger steam loads**
- **Normally non export of electricity**
- **Low emissions – natural gas**

Gas Turbine



Defining Combined Heat & Power (CHP)

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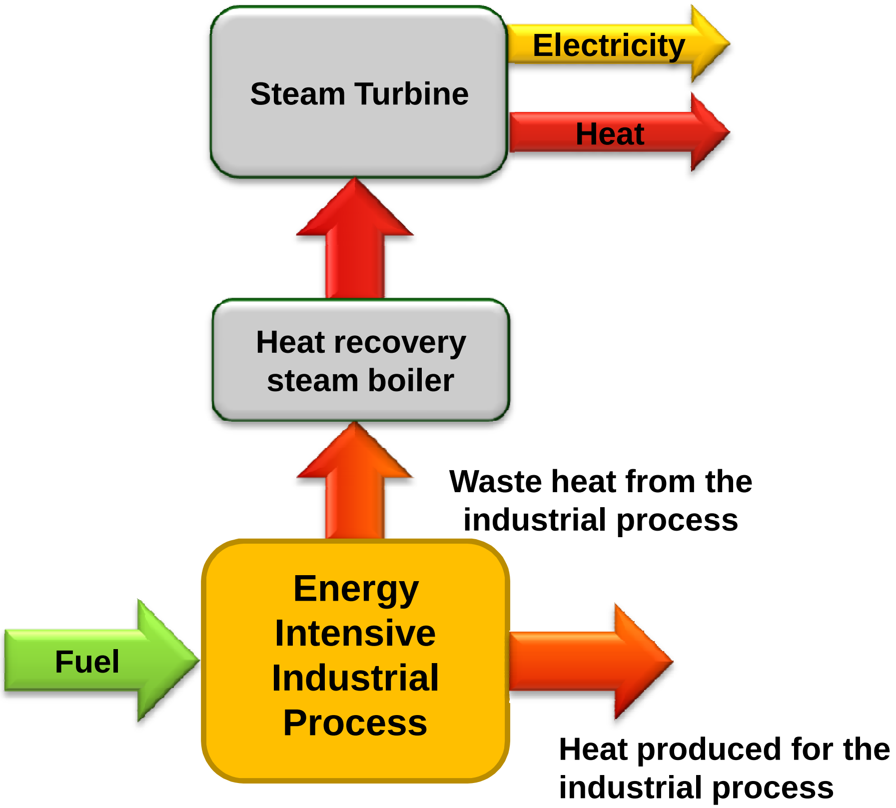
Waste Heat to Power CHP

(also referred to as Bottoming Cycle CHP or Indirect Fired CHP)



- **Fuel first applied to produce useful thermal energy for the process**
- **Waste heat is utilized to produce electricity and possibly additional thermal energy for the process**
- **Simultaneous generation of heat and electricity**
- **No additional fossil fuel combustion *(no incremental emissions)***
- **Normally produces larger amounts electric generation *(often exports electricity to the grid; base load electric power)***
- **Normally requires high temperature (> 800°F) *(low hanging fruit in industrial plants)***

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CHP Is Used at the Point of Demand

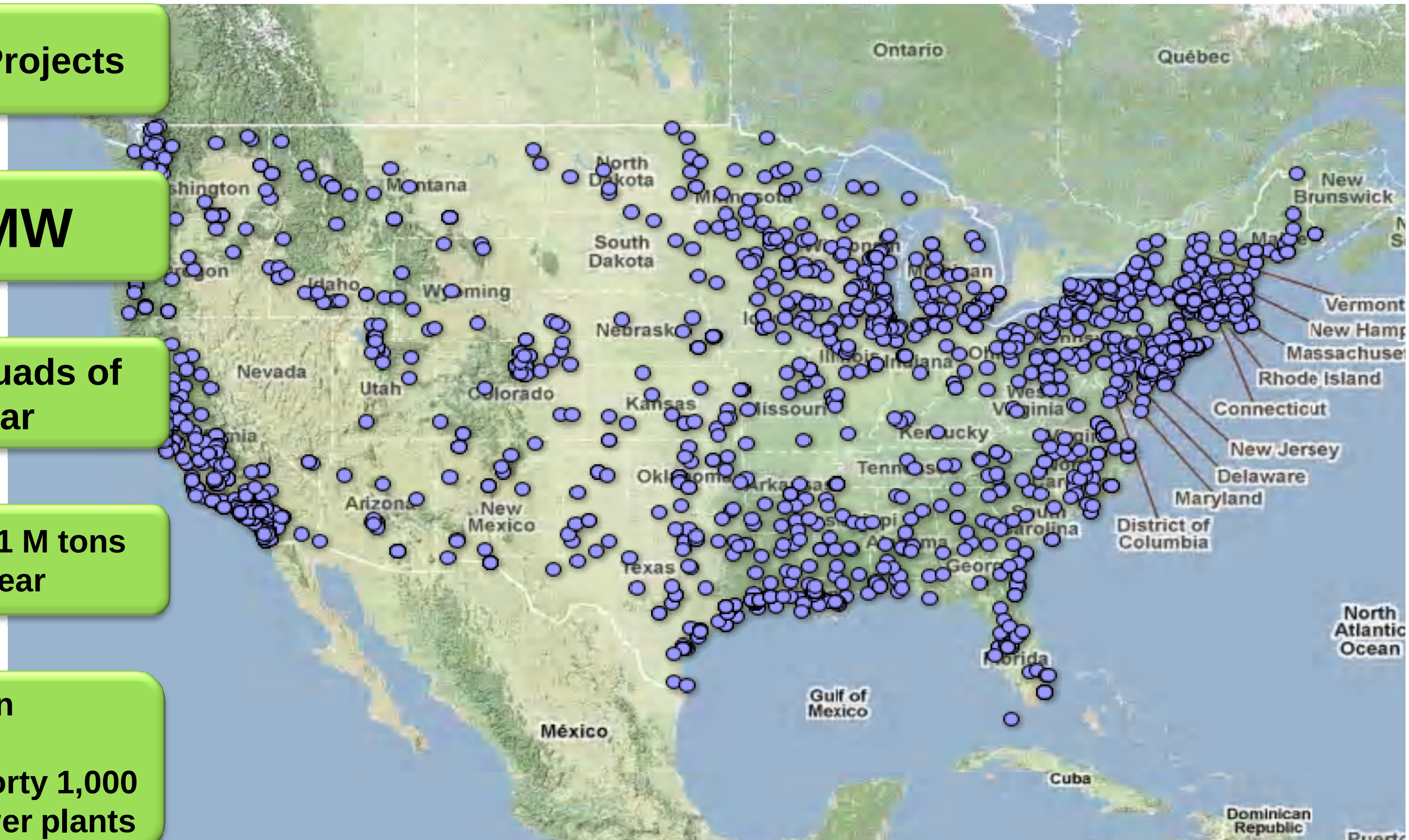
4,100 CHP Projects

81,800 MW

Saves 1.8 quads of fuel each year

Eliminates 241 M tons of CO_2 each year

CO_2 reduction equivalent to eliminating forty 1,000 MW coal power plants



Source: ICF International

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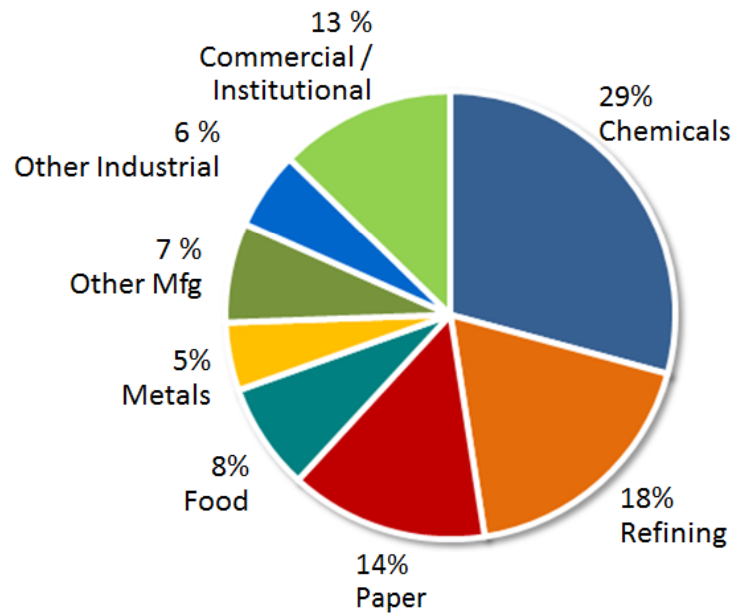
Existing CHP Capacity

- ~ 8% US generating capacity
- ~ 12% total annual MWh generated
- Industrial applications represent 87% of existing capacity
- Commercial/institutional applications represent 13% of existing capacity:
  - Hospitals, Schools, University Campuses, Hotels, Nursing Homes, Office Buildings, Apartment Complexes, Data Centers, Fitness Centers



Source: ICF International

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Why U.S. Businesses Invest in CHP

(> 4,100 installations & ~ 82 GW installed capacity)

- Reduces energy costs for the end-user
- Increases energy efficiency, helps manage costs, maintains jobs
- Reduces risk of electric grid disruptions & enhances energy reliability (Hurricanes Katrina & Sandy; 2004 Blackout)
- Provides stability in the face of uncertain electricity prices
- Used as compliance strategy for emission regulations (Boiler MACT & Reduced Carbon Footprint)

Why More Businesses Do Not Invest in CHP

- Economics not right (long payback periods)
  - Spark Spread not favorable
  - Capital Cost
- Competing for tight capital budgets
- Too much of a hassle
  - Working with utilities may be seen as impediment
- Lack of accurate knowledge & lack of resources to investigate
- To lesser degree, financing and permitting

Attractive CHP Markets

Industrial

- Chemical manufacturing
- Ethanol
- Food processing
- Natural gas pipelines
- Petrochemicals
- Pharmaceuticals
- Pulp and paper
- Rubber and plastics

Commercial

- Data centers
- Hotels and casinos
- Multi-family housing
- Laundries
- Apartments
- Office buildings
- Refrigerated warehouses
- Restaurants
- Supermarkets
- Green buildings

Institutional

- Hospitals
- Landfills
- Universities & colleges
- Wastewater treatment
- Residential confinement

Agricultural

- Concentrated animal feeding operations
- Dairies
- Wood waste (biomass)

Affected Coal and Oil Boilers in the Mid-Atlantic

State	# Facilities	# Coal Units	# Heavy Oil Units	# Light Oil Units
Delaware	3	5	5	0
Maryland	6	5	5	3
New Jersey	6	3	2	10
Pennsylvania	49	62	38	12
Virginia	36	49	14	16
West Virginia	13	36	2	7
Total	113	160	66	48

Affected Boilers in the Mid-Atlantic

State	Coal Total Capacity (MMBtu/hr)	Heavy Oil Total Capacity (MMBtu/hr)	Light Oil Total Capacity (MMBtu/hr)	Total Capacity (MMBtu/hr)
Delaware	693	305	0	998
Maryland	1,993	1,601	320	3,914
New Jersey	146	100	1,307	1,553
Pennsylvania	8,279	4,129	1,103	13,511
Virginia	9,856	1,723	1,496	13,075
West Virginia	29,576	392	196	30,164
Total	50,543	8,250	4,422	63,214

Includes industrial, commercial and institutional boilers only

DOE Boiler MACT Technical Assistance Program

Mid-Atlantic

- The U.S. DOE Mid-Atlantic CEAC is supplementing its normal CHP services by:
- Providing site specific technical and cost information to the 195+ major source facilities (~ 480 boilers) in 12 states currently burning coal or oil (Decision Tree Analysis)
- Meeting with willing individual facility management to discuss “Clean Energy Compliance Strategies” including potential funding and financial opportunities.
- Assisting interested facilities in the implementation of CHP as a compliance strategy

Technical Assistance Approach

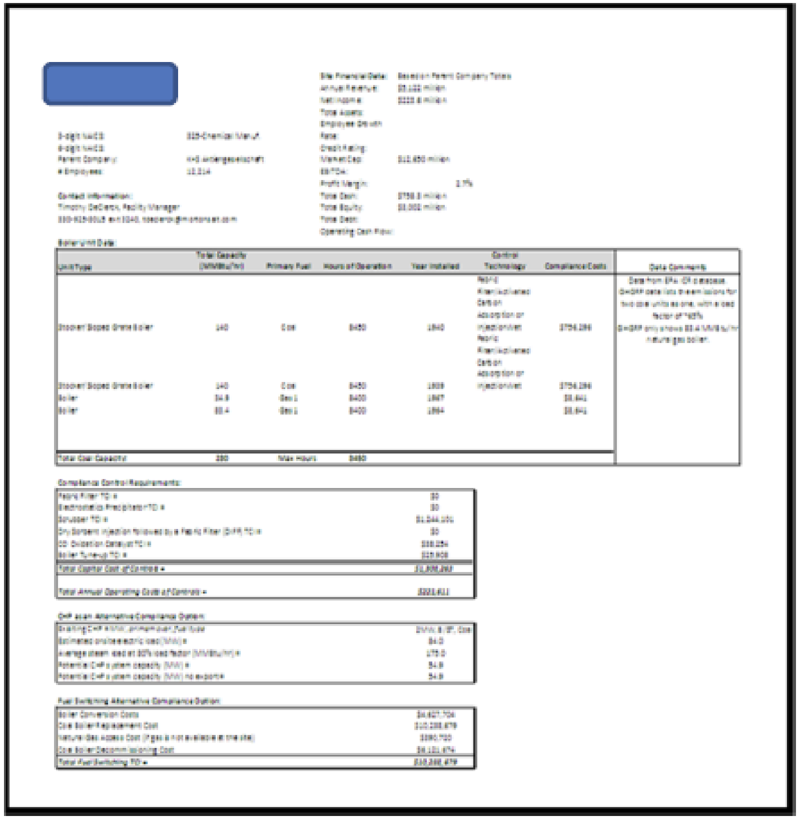
- Contact each facility explaining the program and the analysis being offered (Decision Tree Analysis)
- “Soft Sell” – not attempting to sell a CHP system, rather providing information on an alternative approach that you should consider as you develop your compliance strategy!
- Verify the specific site assumptions being used in the analysis
- Conduct the decision tree analysis (simple spread sheet) comparing strategy options.

Decision Tree Analysis

- Provides comparative cost of compliance options for coal and/or oil fired boilers:
  - Installing control technologies on existing boilers
  - Replacing existing boilers with new natural gas boilers
  - Converting existing boilers for operation on natural gas
  - Replacing existing boiler with a natural gas fueled combustion turbine CHP system

Decision Tree

- Provides available data:
  - General Site information
  - Boiler information/configuration
  - Compliance and conversion cost estimates
- Calculations
  - Average Steam Load
  - CHP Sizing
  - CHP Paybacks compared to other options
  - 5 and 10 year cash flows
  - IRR and NPV



Comparative Cost of Compliance Options

- Calculates the annual fuel use, fuel costs, O&M costs for each option
- Compares the annual operating costs and capital costs
- Calculates simple payback of CHP

Comparative Cost of Compliance Options

	Upgrade Coal Boilers	New Natural Gas Boilers	Boiler Conversion to Natural Gas	Natural Gas CHP
Boiler Capacity, MMBtu/hr input	280.0	280.0	280.0	280.0
Avg Steam Demand, MMBtu/hr	174.7	174.7	174.7	174.7
Boiler Efficiency	78%	80%	70%	NA
CHP Capacity, MW	0	0	0	54.8
CHP Electric Efficiency	NA	NA	NA	37%
Fuel Use, MMBtu/year	1,892,800	1,845,480	2,109,120	4,270,513
Annual Fuel Cost	$4,164,160	$11,072,880	$12,654,720	$25,623,079
Annual O&M Cost	$5,640,544	$2,343,760	$2,678,582	$5,122,835
Annual Compliance O&M	$221,611	NA	NA	NA
Annual Electric Savings				*$27,095,989*
Annual Steam Operating Costs	$10,026,315	$13,416,640	$15,333,302	$3,640,925
Annual Operating Savings (coal compliance)				*$6,375,390*
Annual Operating Savings (gas boiler)				*$9,765,714*
Capital Costs	**$1,308,263**	**$10,288,679**	**$4,627,704**	**$63,858,447**
CHP Incremental costs (coal compliance)				$62,550,184
CHP Payback (coal compliance)				**9.8**
CHP Incremental costs (gas boiler)				$53,569,768
CHP Payback (gas boiler)				**5.5**

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Cash Flows, IRR, NPV

- 5 and 10 year cash flows are calculated for each compliance option
- The 10 year internal rate of return (IRR) and net present value (NPV) are calculated for CHP versus installing compliance controls

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Frequently Asked Questions

- **How accurate is the Decision Tree Analysis results?** The results are only as good as the assumptions utilized. We expect the facilities will update the assumptions after the one-on-one meetings.
- **What are the sources of the facility and unit data assumptions**?
  - ICR – Survey data on boilers, process heater and other combustion units, submitted to EPA (facility & unit level data)
  - ECHO – EPA Enforcement & Compliance History Online database (facility level data on major source polluters)
  - REPIS – NREL Renewable Electric Plant Info System database (facility and unit level data for biomass facilities)
  - MIPD – Major Industrial Plant database (facility data for large industrial plants
  - LBDB – Large Boiler database (facility & unit level data – boilers > 250 MMBtu/hr
  - ELECUTIL – ICF Electric Utility database (facility & unit level data for utility boilers
  - EPA GHGRP – EPA Greenhouse Gas Reporting Program (facility and unit level data for large GHG emitters)

Frequently Asked Questions

- **What is the value of an option that has such a significantly larger first cost?** Investment (with payback) versus a cost - higher efficiencies & lower emissions – potential for lower steam costs
- **As a "rule of thumb," which boilers are most favorable for a CHP control strategy?** Older coal and oil boilers where installing standard control technologies is very expensive and/or converting the existing boiler to natural gas is an option.
- **If the facility wants to further explore CHP, what specific services can the CEAC provide?** Assist in scoping the project (level 1 sizing, costs, design options); assist in securing needed engineering, financial and installation support

Next Steps – Mid-Atlantic

- Mid-Atlantic CEAC will send letters to all affected facilities (coal and oil) explaining the technical assistance program, and follow up with phone calls to establish contacts and obtain permission to continue with analysis
  - If decision tree analysis is favorable, site visits will be made to discuss analysis results. Report will be provided to facility.
- Continue technical assistance as appropriate
- Looking to work with in-state trade associations, utilities and others to spread the word and verify facility contacts

DOE & Mid-Atlantic CEAC Contacts

DOE Headquarters

U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy

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http://www1.eere.energy.gov/manufacturing/distributedenergy/ceacs.html

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States Covered: Virginia, West Virginia, Pennsylvania, New Jersey, Delaware, Maryland and Washington D.C.

Thank You

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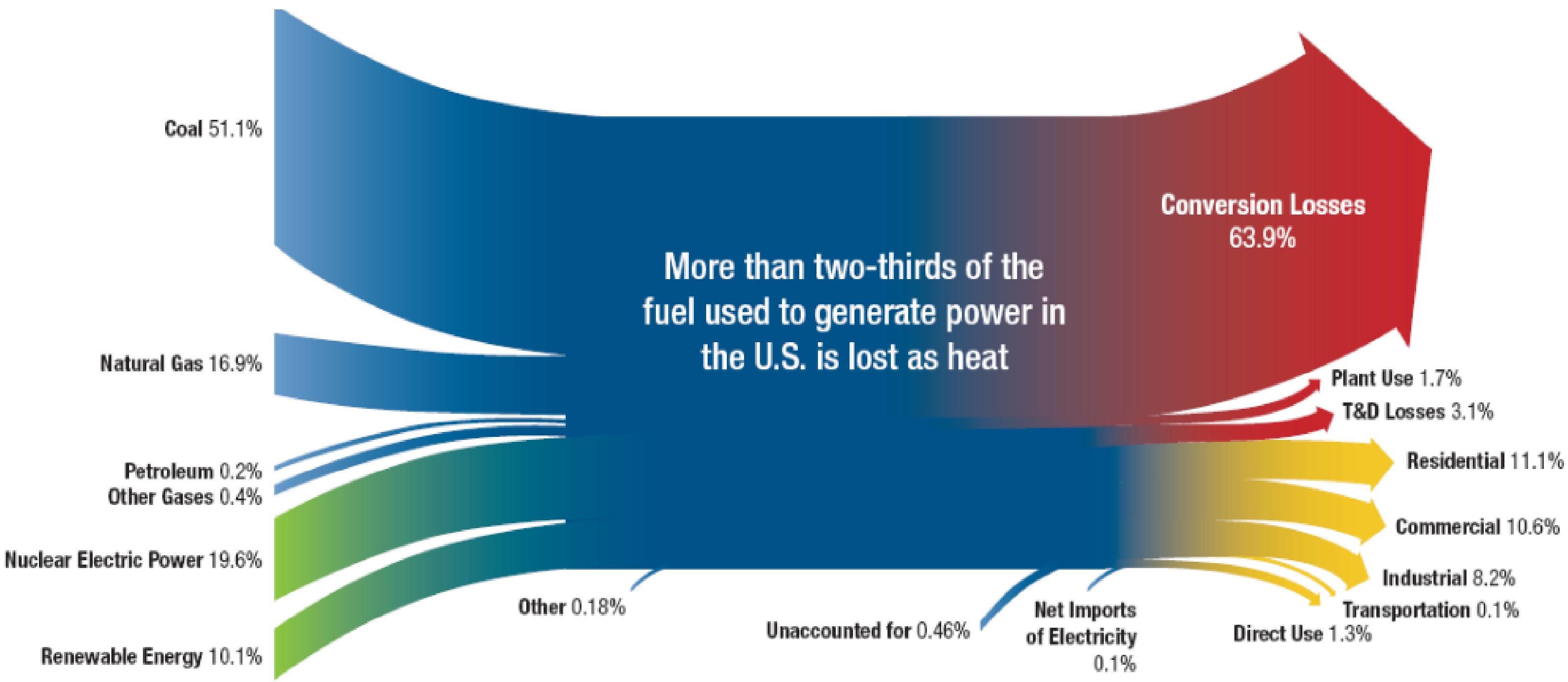
U.S. DOE to offer Technical Assistance

- Ensure that major sources burning coal or oil have information on cost-effective clean energy strategies for compliance
- 5 options study:
  - Upgrade existing boilers with emissions control technologies identified by EPA
  - Convert existing boilers to natural gas- fired boilers
  - Replace existing boilers with natural gas-fired boilers
  - Replace existing boilers with natural gas- fired CHP system and backup boiler
  - Replace existing boilers with natural gas fired CHP system only (no additional boilers)

More information: http://www1.eere.energy.gov/manufacturing/distributedenergy/boilermact.html

Fuel Utilization by U.S. Utility Sector



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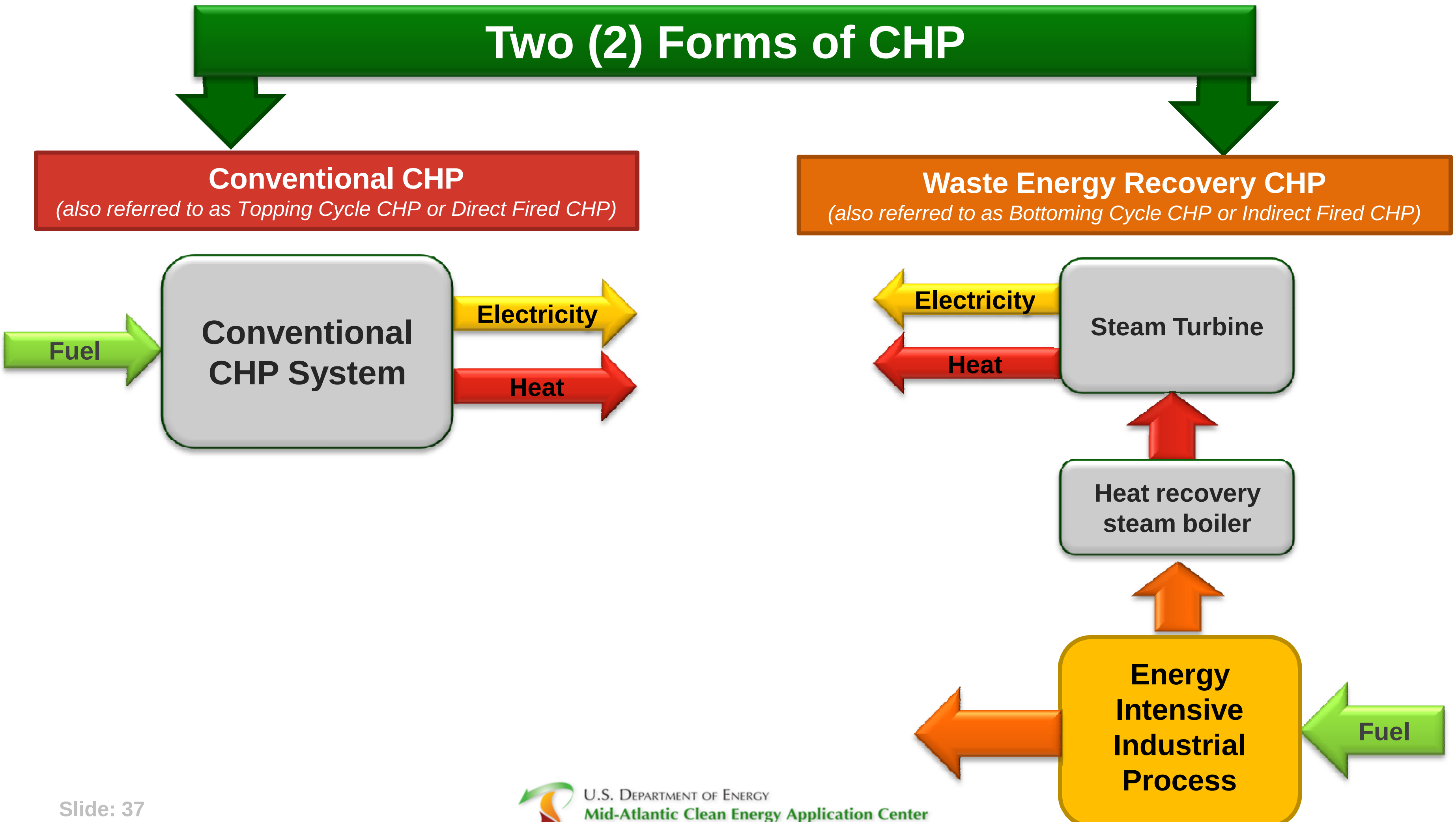

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CHP Gas Combustion Turbines

- Similar to a jet engine as a stream of inlet air is compressed, heat is added and then the high pressure outlet stream turns a reaction turbine at high speed which in turn drives a generator
- Generally used for larger applications (>3MW)
- Good when high pressure steam is required
- Heat Recovery Steam Generators (HRSG)

Source: Industrial Turbine by Siemens Westinghouse
www.siemenswestinghouse.com

Site Boiler & Energy Info

Existing Boilers
Two Coal-fired; 238 MMBtu/hr each; Installed in 1981; 80% efficiency; Average 62% load factor
• One boiler can serve the average facility steam demand 24X7
• Each boiler operates 4,380 hours per year with second boiler serving as backup
• Coal sulfur content is 0.8% by weight
• One bag house for PM control; Staged combustion for NOx control
Two Natural Gas-Fired; 80 MMBtu/hr each; Installed in 1981 for peaking use
• Only one boiler is needed for meeting peaking loads
• Second boiler is a backup boiler
• Boilers operate approximately 80 hours per year
Energy Demands
• Average Annual Electric Demand: 11,000 kW
• Maximum Electric Demand: 17,000 kW
• Average Steam Load at 62% Load Factor: 118 MMBtu/hr
Current Energy Prices
• Electricity: $0.055/kWh
• Natural Gas: $3.25/MMBtu ($4.25/MMBtu used in the Decision Tree Analysis)
• Coal: $4.00/MMBtu

Summary of Economic Results
"Analyzing CHP Options"

	Option #1	Option #2	Option #3	Option #4	Option #5
	Implement Emission Controls to Existing Boiler(s)	Convert Existing Boilers to Nat Gas Fuel	Replace Existing Boilers w/ New Nat Gas Boilers	Replace Existing Boilers w/ CHP System and NG Boiler	Replace Existing Boilers w/ CHP System (No Extra Backup Boiler)
Total Capital Investment [1,2,3,4]	$21,903,455	$7,858,029	$17,208,182	$26,710,091	$18,106,000
Year 1 Steam Operating Costs [5,6,7,8]	$11,557,953	$8,036,498	$7,132,392	$5,241,790	$5,241,790
Year 1 Elec Savings from CHP Gen [9]	0	0	0	$4,769,820	$4,769,820
5 Year Net Cash Flow (Output) [10]	$82,655,853	$48,514,465	$54,698,377	$54,262,662	$45,658,571
10 Year Net Cash Flow (Output) [10]	$151,391,615	$90,448,034	$97,115,092	$85,435,868	$76,831,777
CHP Simple Payback Period (Years) [11]	0.8	6.7	5.0	NA	NA
CHP Option 10 Year IRR [12]	134%	5%	17%	NA	NA
CHP Option 10 Year NPV [12]	$38,834,604	(-$2,263,541)	$4,158,388	NA	NA
Year 1 Total CHP Savings [12]	$6,316,163	$2,794,708	$1,890,602	NA	NA
Year 1 Steam Operating & Electric Costs per Unit Produced, $/hl [15]	$1.60	$1.26	$1.18	$1.00	$1.00

Summary of Economic Results

"Comparing Option #1 to CHP Option #4"

	Option #1	Option #2	Option #3	Option #4	Option #5
	Implement Emission Controls to Existing Boiler(s)	Convert Existing Boilers to Nat Gas Fuel	Replace Existing Boilers w/ New Nat Gas Boilers	Replace Existing Boilers w/ CHP System and NG Boiler	Replace Existing Boilers w/ CHP System (No Extra Backup Boiler)
Total Capital Investment [1,2,3,4]	$21,903,455	$7,858,029	$17,208,182	$26,710,091	$18,106,000
Year 1 Steam Operating Costs [5,6,7,8]	$11,557,953	$8,036,498	$7,132,392	$5,241,790	$5,241,790
Year 1 Elec Savings from CHP Gen [9]	0	0	0	$4,769,820	$4,769,820
5 Year Net Cash Flow (Output) [10]	$82,655,853	$48,514,465	$54,698,377	$54,262,662	$45,658,571
10 Year Net Cash Flow (Output) [10]	$151,391,615	$90,448,034	$97,115,092	$85,435,868	$76,831,777
CHP Simple Payback Period (Years) [11]	0.8	6.7	5.0	NA	NA
CHP Option 10 Year IRR [12]	134%	5%	17%	NA	NA
CHP Option 10 Year NPV [12]	$38,834,604	(-$2,263,541)	$4,158,388	NA	NA
Year 1 Total CHP Savings [12]	$6,316,163	$2,794,708	$1,890,602	NA	NA
Year 1 Steam Operating & Electric Costs per Unit Produced, $/hl [15]	$1.60	$1.26	$1.18	$1.00	$1.00

U.S. Department of Energy
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Promoting CHP, District Energy, and Waste Energy Recovery

Summary of Economic Results

"Comparing Option #2 to CHP Option #4"

	Option #1	Option #2	Option #3	Option #4	Option #5
	Implement Emission Controls to Existing Boiler(s)	Convert Existing Boilers to Nat Gas Fuel	Replace Existing Boilers w/ New Nat Gas Boilers	Replace Existing Boilers w/ CHP System and NG Boiler	Replace Existing Boilers w/ CHP System (No Extra Backup Boiler)
Total Capital Investment [1,2,3,4]	$21,903,455	$7,858,029	$17,208,182	$26,710,091	$18,106,000
Year 1 Steam Operating Costs [5,6,7,8]	$11,557,953	$8,036,498	$7,132,392	$5,241,790	$5,241,790
Year 1 Elec Savings from CHP Gen [9]	0	0	0	$4,769,820	$4,769,820
5 Year Net Cash Flow (Output) [10]	$82,655,853	$48,514,465	$54,698,377	$54,262,662	$45,658,571
10 Year Net Cash Flow (Output) [10]	$151,391,615	$90,448,034	$97,115,092	$85,435,868	$76,831,777
CHP Simple Payback Period (Years) [11]	0.8	6.7	5.0	NA	NA
CHP Option 10 Year IRR [12]	134%	5%	17%	NA	NA
CHP Option 10 Year NPV [12]	$38,834,604	(-$2,263,541)	$4,158,388	NA	NA
Year 1 Total CHP Savings [12]	$6,316,163	$2,794,708	$1,890,602	NA	NA
Year 1 Steam Operating & Electric Costs per Unit Produced, $/hl [15]	$1.60	$1.26	$1.18	$1.00	$1.00

Summary of Economic Results

"Comparing Option #3 to CHP Option #4"

	Option #1	Option #2	Option #3	Option #4	Option #5
	Implement Emission Controls to Existing Boiler(s)	Convert Existing Boilers to Nat Gas Fuel	Replace Existing Boilers w/ New Nat Gas Boilers	Replace Existing Boilers w/ CHP System and NG Boiler	Replace Existing Boilers w/ CHP System (No Extra Backup Boiler)
Total Capital Investment [1,2,3,4]	$21,903,455	$7,858,029	$17,208,182	$26,710,091	$18,106,000
Year 1 Steam Operating Costs [5,6,7,8]	$11,557,953	$8,036,498	$7,132,392	$5,241,790	$5,241,790
Year 1 Elec Savings from CHP Gen [9]	0	0	0	$4,769,820	$4,769,820
5 Year Net Cash Flow (Output) [10]	$82,655,853	$48,514,465	$54,698,377	$54,262,662	$45,658,571
10 Year Net Cash Flow (Output) [10]	$151,391,615	$90,448,034	$97,115,092	$85,435,868	$76,831,777
CHP Simple Payback Period (Years) [11]	0.8	6.7	5.0	NA	NA
CHP Option 10 Year IRR [12]	134%	5%	17%	NA	NA
CHP Option 10 Year NPV [12]	$38,834,604	(-$2,263,541)	$4,158,388	NA	NA
Year 1 Total CHP Savings [12]	$6,316,163	$2,794,708	$1,890,602	NA	NA
Year 1 Steam Operating & Electric Costs per Unit Produced, $/hl [15]	$1.60	$1.26	$1.18	$1.00	$1.00

Summary of Economic Results

	Option #1	Option #2	Option #3	Option #4	Option #5
	Implement Emission Controls to Existing Boiler(s)	Convert Existing Boilers to Nat Gas Fuel	Replace Existing Boilers w/ New Nat Gas Boilers	Replace Existing Boilers w/ CHP System and NG Boiler	Replace Existing Boilers w/ CHP System (No Extra Backup Boiler)
Total Capital Investment [1,2,3,4]	$21,903,455	$7,858,029	$17,208,182	$26,710,091	$18,106,000
Year 1 Steam Operating Costs [5,6,7,8]	$11,557,953	$8,036,498	$7,132,392	$5,241,790	$5,241,790
Year 1 Elec Savings from CHP Gen [9]	0	0	0	$4,769,820	$4,769,820
5 Year Net Cash Flow (Output) [10]	$82,655,853	$48,514,465	$54,698,377	$54,262,662	$45,658,571
10 Year Net Cash Flow (Output) [10]	$151,391,615	$90,448,034	$97,115,092	$85,435,868	$76,831,777
CHP Simple Payback Period (Years) [11]	0.8	6.7	5.0	NA	NA
CHP Option 10 Year IRR [12]	134%	5%	17%	NA	NA
CHP Option 10 Year NPV [12]	$38,834,604	(-$2,263,541)	$4,158,388	NA	NA
Year 1 Total CHP Savings [12]	$6,316,163	$2,794,708	$1,890,602	NA	NA
Year 1 Steam Operating & Electric Costs per Unit Produced, $/hl [15]	$1.60	$1.26	$1.18	$1.00	$1.00

Energy Price Sensitivity Analysis

				Simple Payback of CHP Option #4 compared to Other Options (years)			10 Year IRR of CHP Option #4 compared to Other Options		
Scenario (#)	Year 1 Price of Electricity ($/kWh)	Year 1 Price of Nat Gas ($/MMBtu)	Annual Elec Price Escalation	Option #1	Option #2	Option #3	Option #1	Option #2	Option #3
1	$0.055	$3.25	2.5%	0.6	6.1	4.0	171%	9%	24%
2	$0.055	$4.25	2.5%	0.8	6.7	5.0	134%	5%	17%
3	$0.055	$5.25	2.5%	1.1	7.6	6.7	97%	0%	10%
4	$0.065	$3.25	2.5%	0.5	4.7	2.9	189%	16%	34%
5	$0.065	$4.25	2.5%	0.7	5.1	3.4	152%	13%	28%
6	$0.065	$5.25	2.5%	0.9	5.6	4.2	115%	9%	22%
7	$0.055	$3.25	5.0%	0.6	6.1	4.0	172%	14%	28%
8	$0.055	$4.25	5.0%	0.8	6.7	5.0	136%	11%	22%
9	$0.055	$5.25	5.0%	1.1	7.6	6.7	100%	7%	17%
10	$0.065	$3.25	5.0%	0.5	4.7	2.9	190%	21%	38%
11	$0.065	$4.25	5.0%	0.7	5.1	3.4	154%	18%	33%
12	$0.065	$5.25	5.0%	0.9	5.6	4.2	118%	15%	28%

Discussions and Next Steps
Interest in CHP…?

- Energy pricing
- Tax incentives
- Financing options
- Adapting existing generation
- Refining study
- Electric reliability
- Organizational sustainability goals
- Other facilities

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Promoting CHP, District Energy, and Waste Energy Recovery

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